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Optiflux: a tool for measuring wild animal population fluxes for the optimization of road infrastructures

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Abstract

In West European countries natural habitats are often fragmented. In those countries fragmentation is both characterized by an increase in the number of habitat fragments and a decrease in their size, leading to animal population isolation. The geometry of linear infrastructures (e.g., roads, railways) is not so much a cause of destruction of animal habitats, but rather it acts more as a barrier between fragments. If we consider linear infrastructure as a barrier in landscapes, it is important to study biological fluxes between landscape features before deciding the final route of such infrastructures. OptiFlux development is based on the "resistance concept," developed by G. Pain for his Ph.D. (2001) for SCETAUROUTE and the French Ministry of Environment and the Ministry of Transport. OptiFlux is an automatic GIS space analysis device. It is designed for the prediction and identification of the effects of linear infrastructure on the territorial occupation and viability of the animal populations concerned. OptiFlux can also be used to assess the relevance of fauna passages and, consequently, to optimize their final location and quantities. OptiFlux is crossing land use and environmental data, correlated with the ecological requirements of the species studied. OptiFlux is based on a population viability analysis, applying the SCETAUROUTE Arc View GIS standard. The innovative aspect of OptiFlux is its automated diagnostic approach, with the cross-relation of space and biological data. There are three direct applications for the tool: • Identification of routes having least impact on wild animal population flows • Optimization of the number/location of fauna passages for the benefit of wild animals • Simulation of the positive effect of the fauna passages proposed OptiFlux provides a preliminary approach for a quick identification of the critical areas to be taken into account for design and estimation of the infrastructure. However, it does not eliminate the need for expertise and verification of the results obtained by a field biologist. OptiFlux is a project optimization instrument, helping with the decision making process, concerning the necessity and relevance of the improvements retained. It is also a tool that provides images of future scenarios once the project is realized. OptiFlux has been tested on many species, such as Mustela lutreola, Osmoderma eremita, species of major importance in terms of the European wildlife heritage (threatened species), and Capreolus capreolus, Cervus elaphus, Sus scrofa, species encountered in the majority of projects. Several organizations have already expressed interest in this tool, such as the ONCFS (French National Hunting and Wildlife Authority), various French motorway companies, the IAURIF (Ile de France Regional Urban Planning and

Development Institute), and the Direction Régionale de l'Equipement du Nord Pas de Calais.

OptiFlux: A Tool For Measuring Wild Animal Population Fluxes for the Optimization of Road Infrastructures

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Abstract: In West European countries natural habitats are often fragmented. In those countries fragmentation is both characterized by an increase in the number of habitat fragments and a decrease in their size, leading to animal population isolation. The geometry of linear infrastructures (e.g., roads, railways) is not so much a cause of destruction of animal habitats, but rather it acts more as a barrier between fragments. If we consider linear infrastructure as a barrier in landscapes, it is important to study biological fluxes between landscape features before deciding the final route of such infrastructures. OptiFlux development is based on the "resistance concept," developed by G. Pain for his Ph.D. (2001) for SCETAUROUTE and the French Ministry of Environment and the Ministry of Transport.

OptiFlux is an automatic GIS space analysis device. It is designed for the prediction and identification of the effects of linear infrastructure on the territorial occupation and viability of the animal populations concerned. OptiFlux can also be used to assess the relevance of fauna passages and, consequently, to optimize their final location and quantities. OptiFlux is crossing land use and environmental data, correlated with the ecological requirements of the species studied. OptiFlux is based on a population viability analysis, applying the SCETAUROUTE Arc View GIS standard. The innovative aspect of OptiFlux is its automated diagnostic approach, with the cross-relation of space and biological data. There are three direct applications for the tool:

- Identification of routes having least impact on wild animal population flows
- Optimization of the number/location of fauna passages for the benefit of wild animals
- Simulation of the positive effect of the fauna passages proposed

OptiFlux provides a preliminary approach for a quick identification of the critical areas to be taken into account for design and estimation of the infrastructure. However, it does not eliminate the need for expertise and verification of the results obtained by a field biologist. OptiFlux is a project optimization instrument, helping with the decision making process, concerning the necessity and relevance of the improvements retained. It is also a tool that provides images of future scenarios once the project is realized.

OptiFlux has been tested on many species, such as *Mustela lutreola*, *Osmoderma eremita*, species of major importance in terms of the European wildlife heritage (threatened species), and *Capreolus capreolus*, *Cervus elaphus*, *Sus scrofa*, species encountered in the majority of projects. Several organizations have already expressed interest in this tool, such as the ONCFS (French National Hunting and Wildlife Authority), various French motorway companies, the IAURIF (Ile de France Regional Urban Planning and Development Institute), and the Direction Régionale de l'Equipement du Nord Pas de Calais.

Introduction

The research program for OptiFlux was launched following research developed for a Ph.D. thesis (G. Pain 2001). The Ph.D. was directed by J. Baudry (Institut National de Recherche Agronomique - INRA), co-financed and co-directed by SETRA (Service d'Etude Technique des Routes et Autoroutes), the French Ministry of Environment and SCETAUROUTE[1]. This research has led to the development of a software tool capable of analyzing both landscape and spatial structures of an animal population. This software was named "LandPop" (**Land**scape to **Pop**ulation spatial structure) and has remained at the testing stage on virtual landscape and virtual species.

However, "LandPop" was a complex tool that could not be used easily outside research laboratories. It quickly reached its limits for infrastructure projects. That is why SCETAUROUTE has decided to launch a second phase for this research program. It was decided to design a new tool, based on "Landpop," that would be easier to use and immediately operational for infrastructure studies (highways, railroads, canals, etc.).

I chose to develop OptiFlux with a GIS (Arcview). Development and test phases took place between 2002 and 2004. OptiFlux was developed and tested by the environmental department of SCETAUROUTE and experts for the animal species concerned.

Concept

The OptiFlux concept is based on an evaluation of the spatial distribution of an animal population according to its ecological requirements. OptiFlux also allows the evaluation of the effect of a project that modifies landscape compositions and that contributes to territory fragmentation.

The OptiFlux concept requires knowledge of landscape ecology principles, such as habitats (i.e., the quality of the environment in relation to the species' ecological requirements) and ecosystem functioning (i.e., the natural habitat's role in the species' ecology, feeding, breeding, migration, etc.).

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[1] **SCETAUROUTE SA (EGIS Group)** is a French consulting firm which works all over the world. Founded in 1970 by the major French toll motorway companies to create a center of excellence in the field of motorway engineering, SCETAUROUTE has accumulated experience in project management, design, construction supervision, and assistance to highway and motorway operations at an unique scale. SCETAUROUTE has now extended its activities towards other transport infrastructures, in particular urban, railways, airports, navigable waterways projects, optical fibres and pipelines.

The OptiFlux concept is also based on the resistance of the natural environment to an animal species presence. This resistance is a variable resulting from various factor combinations, such as the frequentation or avoidance of a natural habitat, the death rate, and the energy spent in migrating within this natural habitat.

The natural habitat of the species is considered as being the most favorable; whereas, habitats that show the highest resistance rates are impassable obstacles, such as transport infrastructures, especially when they are fenced or when the traffic is very heavy. Intermediate rates are given according to the attractiveness of the habitat for the species.

Table 1. Excerpt of a species sheet: resistance values

Type of ground occupation	Entrance	Source of database		Class of resistance	Resistance coefficient
		Code CLC (niveau 3)	Code CB		
Continuous urbanization		111		strongly avoided	10000
Discontinuous urbanization		112		strongly avoided	10000
Arable land		211		Neutral	
Vine		221		Neutral	
orchards		222		Neutral	
Meadow		231		Neutral	
Agricultural territories with natural vegetation		243		Neutral	
Forest of deciduous trees		**311**		**Strongly preferred**	**1**
Forest of conifers		**312**		**Strongly preferred**	**1**
Mixed forest		**313**		**Strongly**	**1**

At this stage the scientific knowledge about species biology is fundamental. This knowledge conditions the assignment of the resistance coefficient given to every type of habitat. (MCR– Knaapen et *al.* 1992). It results in the MCR (Minimal Cumulated Resistance). The MCR gives weighted distances that are not the shortest possible but that reflect the resistance of the habitat crossed. These MCR would also give a "weighted cost."

The dispersion equation would have the following form: $MCR = D_{ij} \times r$ where:

- D_{ij} = covered distance between i and j in different habitats
- r = resistance coefficient of every crossed habitat

If r = 1, then D_{ij} = Dmax, if r=100, then D_{ij} = Dmax/100

Dispersion rates are meaningful only if resistance has biologic reality.

The use of this tool is making possible diagnostics on very large study areas. For this purpose, it is necessary to use geographic data of land uses. Many databases are available (Corine Land Cover, Corine Biotop, etc.) and also several regional databases, like SIGALE in the Nord Pas de Calais Area, for example. The right scale for the spatial database is fundamental because it influences the result's precision and validity. It has to be adapted to the species' territory scale. For that reason some studies require a customized database scale to the dimension of the study area. Small study territories, such as the ones used for insects or amphibians, are good examples.

Examples

I chose three examples that illustrate the importance of the spatialized database in order to have good quality results. The choice of the spatialized database depends on the dimension of the vital area of the species to be studied.

Large mammal case: the Red Deer (*Cervus elaphus*)
As the Red Deer occupies a large territory (2000 ha), it is necessary to use a database such as Corine Land Cover.

Figure 1 shows a large territory extending on approximately 300 km. The Red Deer habitat appears in green, while favorable habitat for daily migration appears in yellow, and the dispersion, in brown.

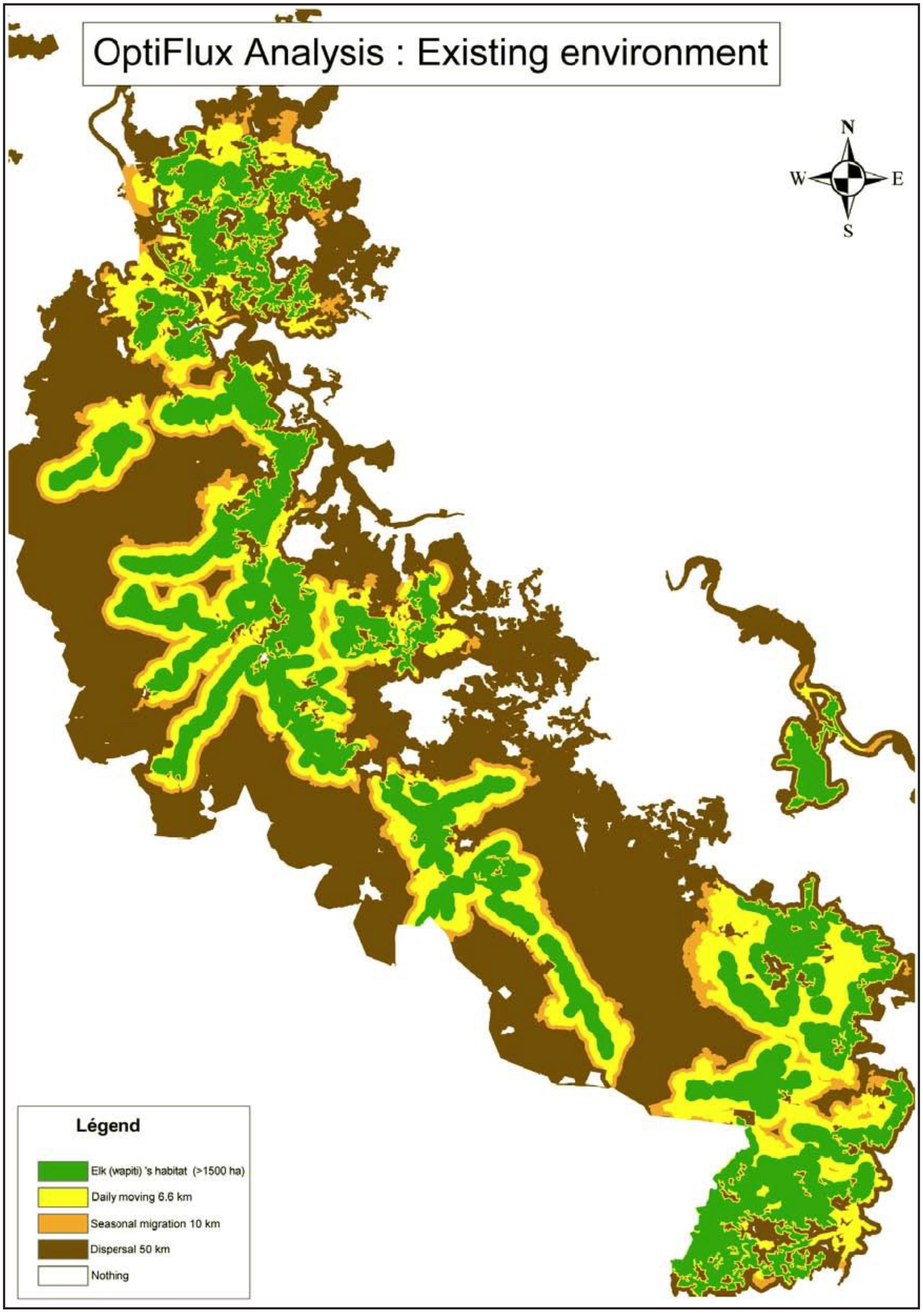

Figure 1. OptiFlux analysis: existing environment.

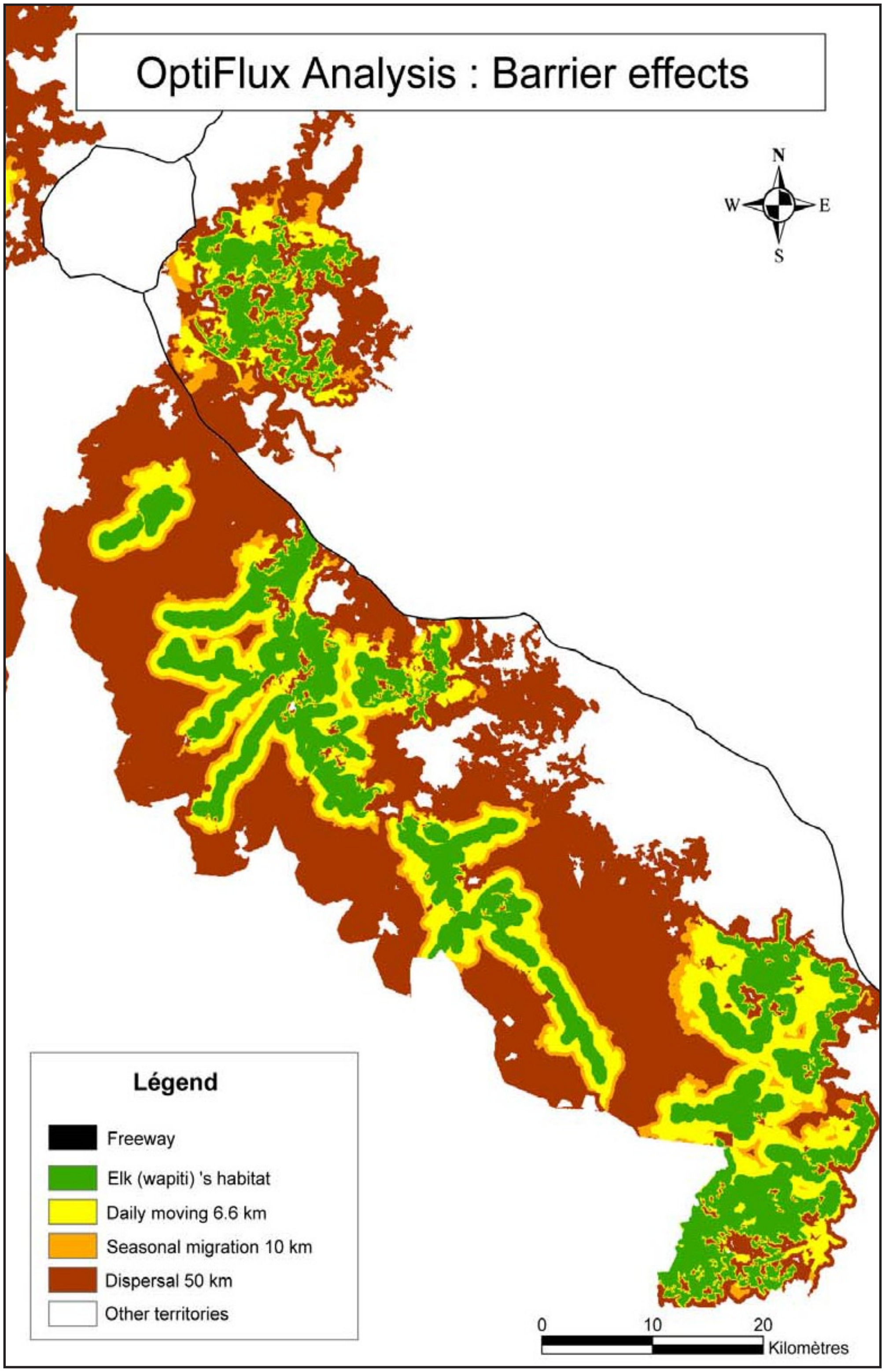

Figure 2. OptiFlux analysis: barrier effects.

In figure 2, the infrastructure crosses this territory from one side to the other. It is a fenced freeway that constitutes an impassable barrier for animals. Impact simulation is shown.

The territory disappearance forecast for the species and the significant reduction of the habitat available for the species can be also observed.

It is the territory fragmentation that could lead to genetic isolation of some animal populations.

In the next step (figure 3), OptiFlux is used to locate the best position for fauna passages. When three fauna passages are installed, connectivity of existing habitats is almost totally kept. A few biological corridors are not restored, but they do not link centers of habitats.

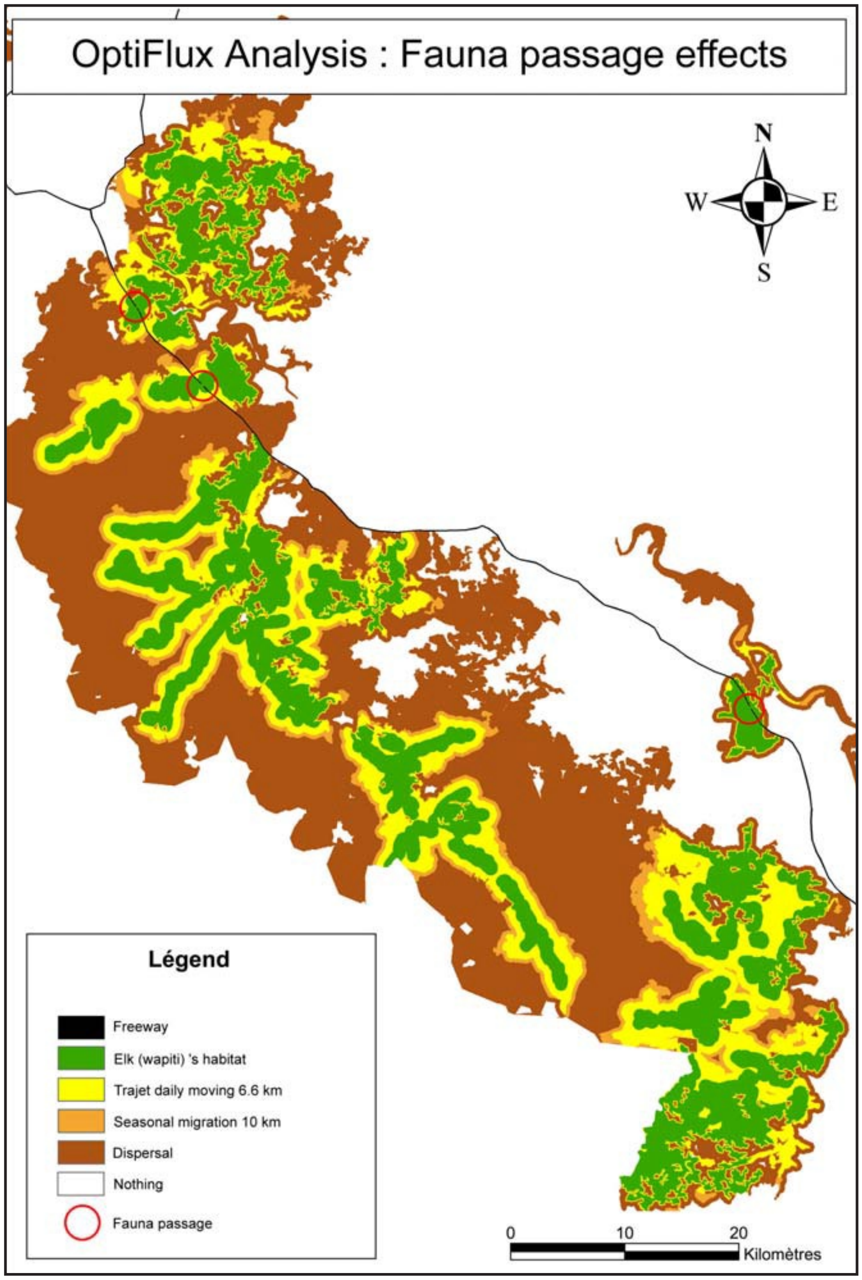

Figure 3. OptiFlux analysis: fauna passage effects.

Thus, at a study stage, simulations on OptiFlux show the best locations for fauna crossover passages for efficient restoration of significant biological corridors. This is particularly useful if, for financial reasons, all of them cannot be implemented.

Small mammal case: the European mink (*Mustela lutreola*)
The European mink is a small territory species (25 ha). Its territory is closely linked with wet habitats that minks almost never leave. For that reason, it is necessary to use a more detailed database, such as Corine Biotope. In our case study, we have used an existing and customized database, constructed to study land value. This was built from aerial photos and site visits for verification. The following map shows likely migration of the European mink.

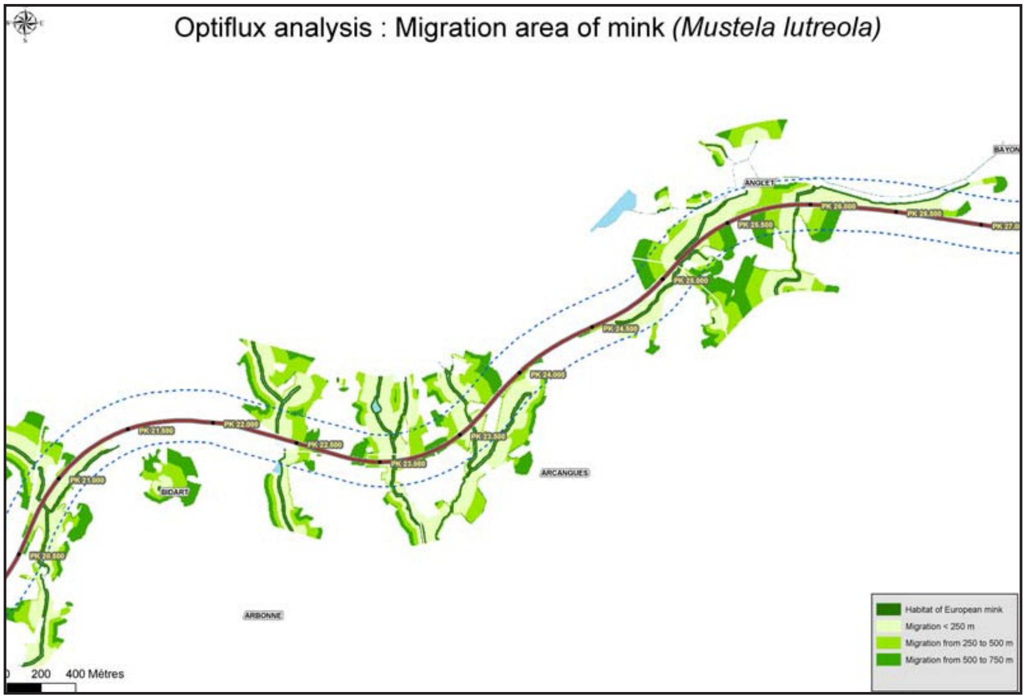

Figure 4. OptiFlux analysis: migration area of mink (*Mustela lutreola*).

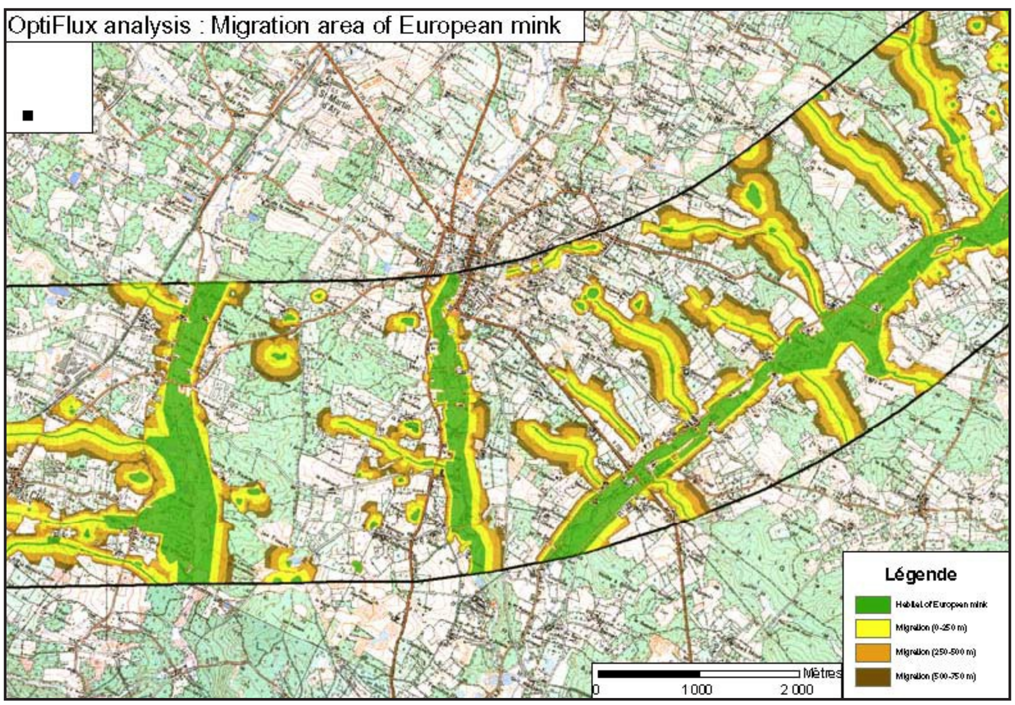

Figure 5. OptiFlux analysis: migration area of European mink.

The results obtained with OptiFlux have been controlled by a French mink expert, and it appears that they are coherent with the species' known dispersion.

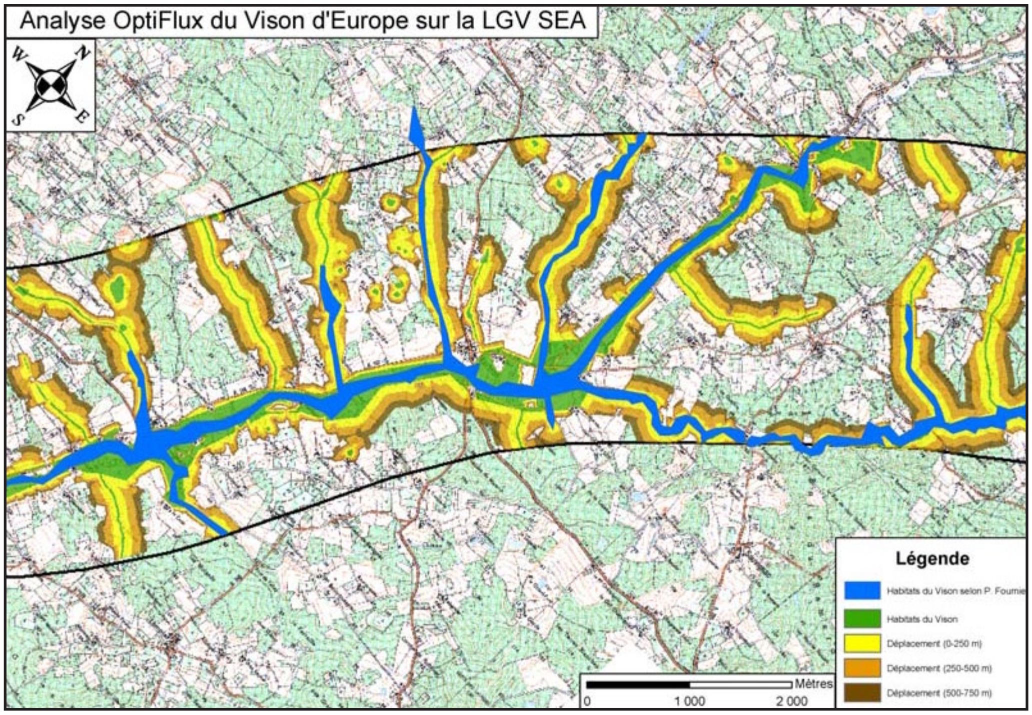

Figure 6. Analyse OptiFlux du Vison d'Europe sur la LGV SEA.

Therefore, on the same principle as that for the Red Deer, we can obtain the same simulations.

Insect species: the Hermit beetle (*Osmoderma eremita*)
The Hermit beetle (*Coleoptera Scaraboidea*) is a species that has a small dispersion area (approximately 500 m). This map (fig. 7) shows, on a 50-km stretch of freeway, locations where the hermit beetle is present or potentially present. The spatialized database was put together at a scale of 1/5000^{e} for land acquisition studies. We have reused and completed it with biological data on the quality and structure of hedges. For financial reasons, it was not possible to implement its habitat everywhere (network of hedges). Choices were needed. To the right, connected areas showing either a definite presence or probable habitats for the Hermit beetle are shown.

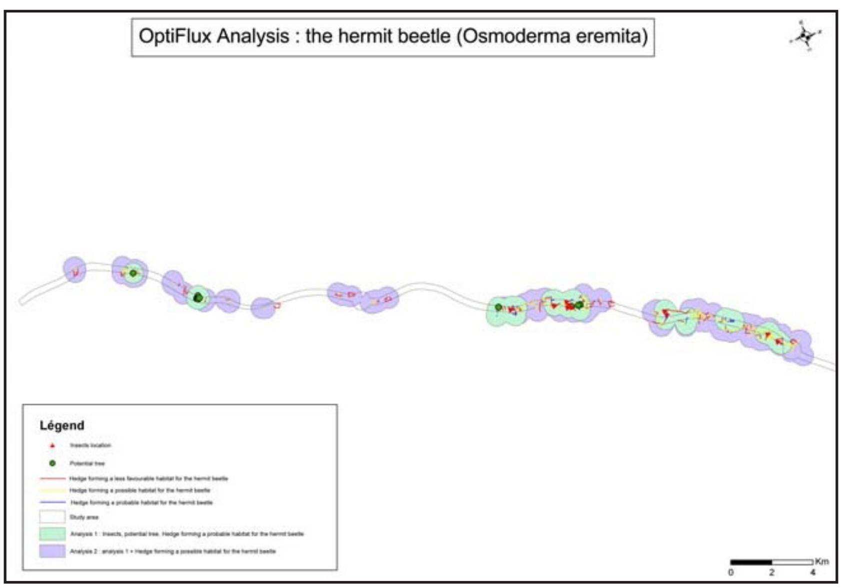

Figure 7. OptiFlux analysis: the hermit beetle (*Osmoderma eremita*).

It is only in these locations that hedge networks have been implemented in order to recreate habitat connectivity, essential for the specie's expansion.

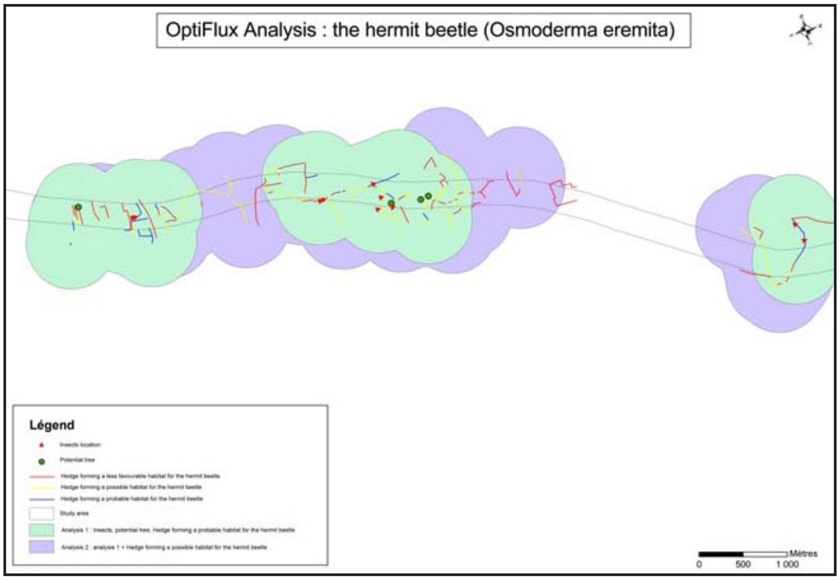

Figure 8. Zoom from figure 7.

OptiFlux helped us to select the locations where mitigation measures should have been realized in order to restore the Osmoderma eremita habitat connectivity with the best value.

Conclusions

The innovative aspect of OptiFlux is its automated diagnostic approach, with cross-relation of spatial and biological data, on large territories and at the initial stages of the project. It is a user-friendly tool (much more so than LandPop) that uses ArcView (GIS) and a plug-in called "Spatial Analyst."

OptiFlux provides a preliminary approach for a quick identification of the critical areas to be taken into account for design and cost estimate of the infrastructure. However, it does not eliminate the need for expertise and verification of the OptiFlux results made by a field biologist.

OptiFlux is a project optimization instrument, which helps in the decision-making process, concerning the necessity and relevance of the improvements retained. There are three direct applications for the tool:

- Identification of routes having the least impact on wild animal population fluxes and their habitats.
- Optimization of the number and location of fauna passages for the benefit of wild animals, and reduction of the points of conflicts between infrastructures (road, highway, railway) and biological corridors.
- Simulation of the positive effects of the proposed fauna passages or biotopes (amphibian ponds, for example) for a better choice of installations and for a better re-establishment of the connectivity of the habitats.

We are currently using this tool for the mammal group and we are continuing to develop the biological database (species sheet). We are working in particular on the taxonomic groups of amphibians and the birds.

Biographical Sketch: Dr. Philippe Thiévent (Ph.D. biology/entomology) is the technical manager of the Environment Department of SCETAUROUTE (EGIS Group). He is an internationally recognized expert on environmental impact assessment of major projects. He takes part in many French and European work groups targeting the improvement of transport infrastructures and their integration in the environment. Dr. Thiévent also participates in the development of technical guides on these subjects. He develops activities relating to recreation or improvement of river banks by methods of "ecological engineering," activities relating to the study of natural habitats' severance and fragmentation, and activities related to associated mitigation techniques.